The Relativistic Heavy Ion Collider

BNL/PHENIX Group

David Morrison

DOE NP RHIC Science & Technology Review
23 – 25 August 2016

BROOKHAVEN NATIONAL LABORATORY
a passion for discovery

Office of Science
U.S. DEPARTMENT OF ENERGY

Group composition and responsibilities

- Primary responsibility is operation of PHENIX experiment and hosting of activities – e.g, visitor support, computing, meetings, publication support – to optimize scientific output of the collaboration.
- Group leader (Morrison), two deputies (Steinberg, Woody) – work in conjunction with leaders of specific activities (e.g, Chiu and O'Brien and Haggerty) to coordinate effort of group and manage change
- Activities directed toward sPHENIX
  - technical crew now working on PHENIX R&R
  - detector prototypes and test beam activities (Woody, Mannel, Stoll, Haggerty, Huang, Purschke, Franz, technicians)
  - sPHENIX project management (O'Brien, Haggerty, Sourikova, Lynch)
- ATLAS HI physics analysis, ZDC project lead (Steinberg, Perepelitsa)
- Generic R&D (LDRD, EIC R&D): Woody, Azmoun, Stoll, …
- Number of scientists, technical staff: FTEs (put in specifics)

Group representation in leading roles

- PHENIX: former Co-spokesperson (Morrison), Operations director (Chiu), Data production manager (Franz), Online computing coordinator (Purschke), …

- sPHENIX: Co-spokesperson (Morrison), Project coordinator (O'Brien), Project

- ATLAS: HI co-convener (Steinberg 10/2016), ZDC lead (Steinberg)

(replace with Org charts)

Operations activities

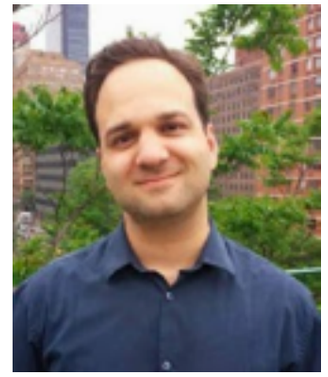
- add slide from Mickey Chiu about Run-15/16 activities

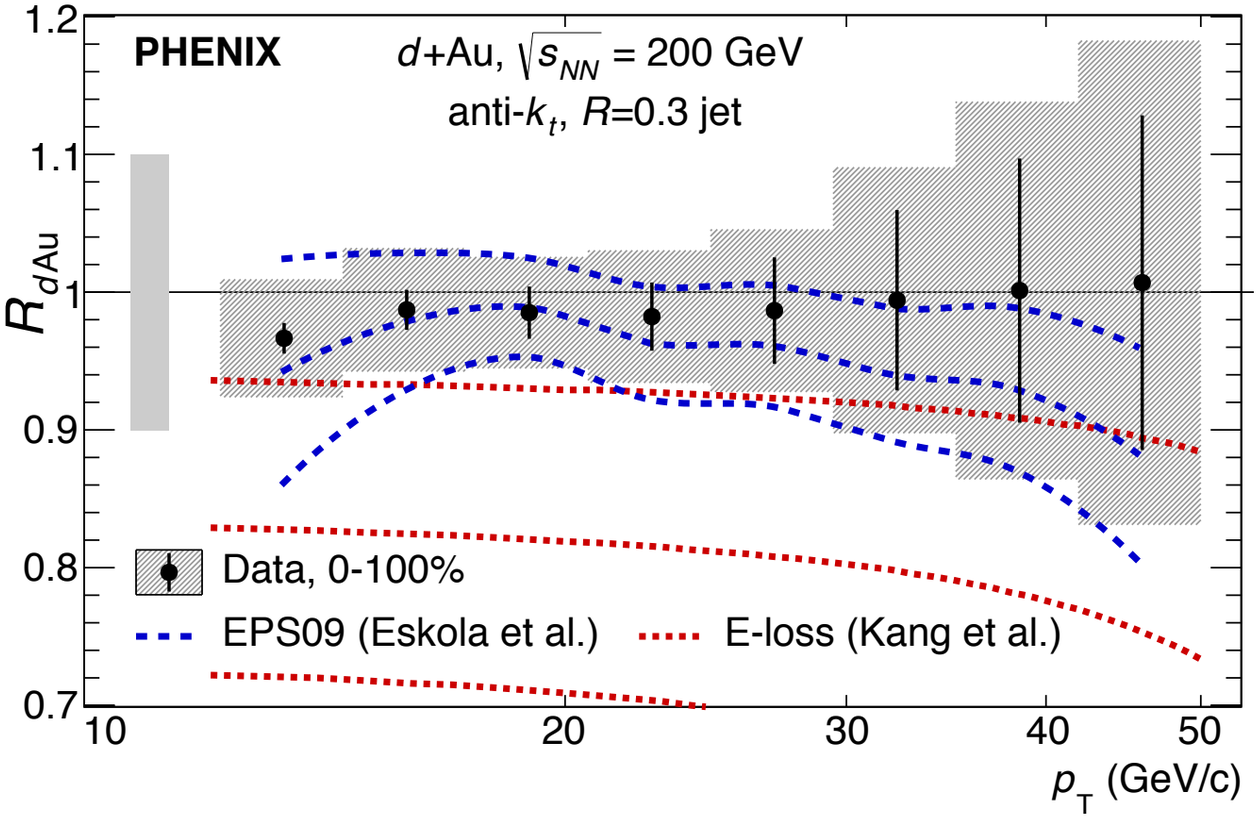
Scientific productivity since 2014 S&T review

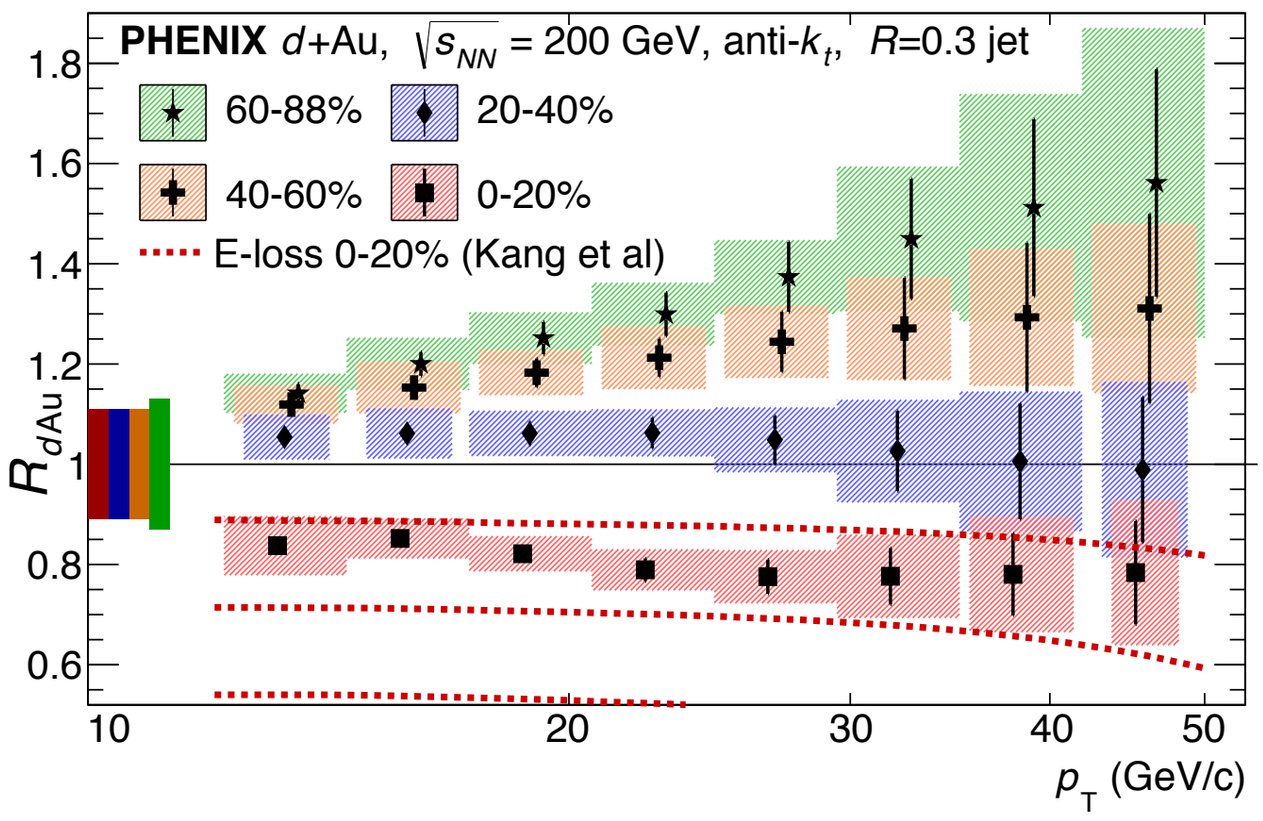
- 5 IAC spots
- 8 LOC spots (including conveners at conferences)
- 45 invited seminars and talks
- Primary authors on N refereed papers (PHENIX, ATLAS, sPHENIX, few author, and community white papers)

Jet production in *d*+Au

Dennis Perepelitsa
one of primary authors
Goldhaber Fellow
BNL ⇒ Colorado

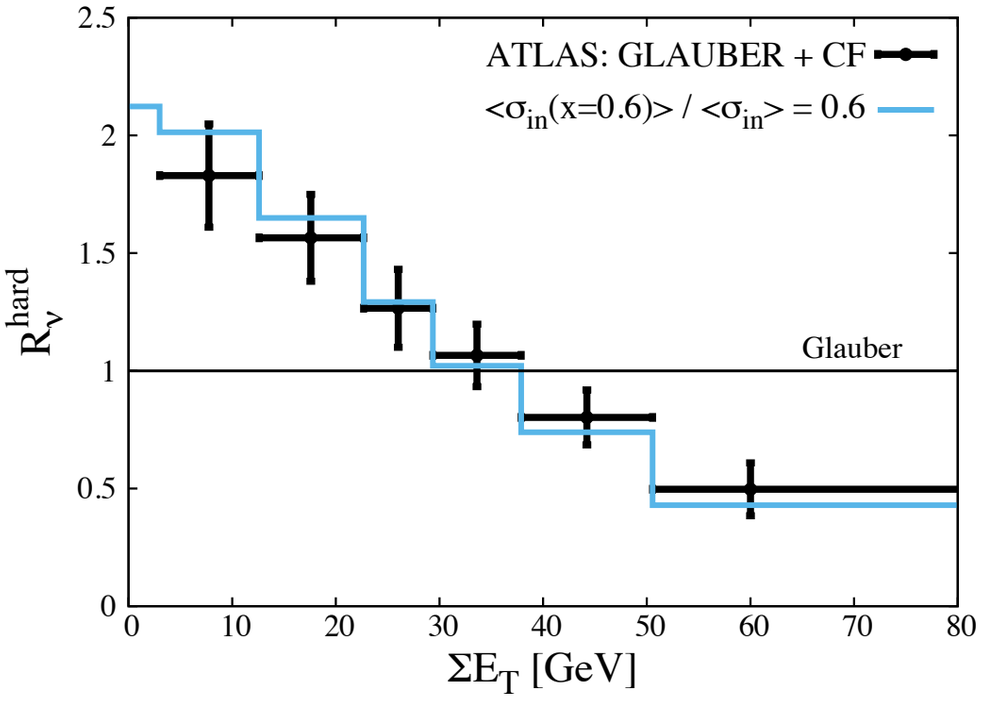


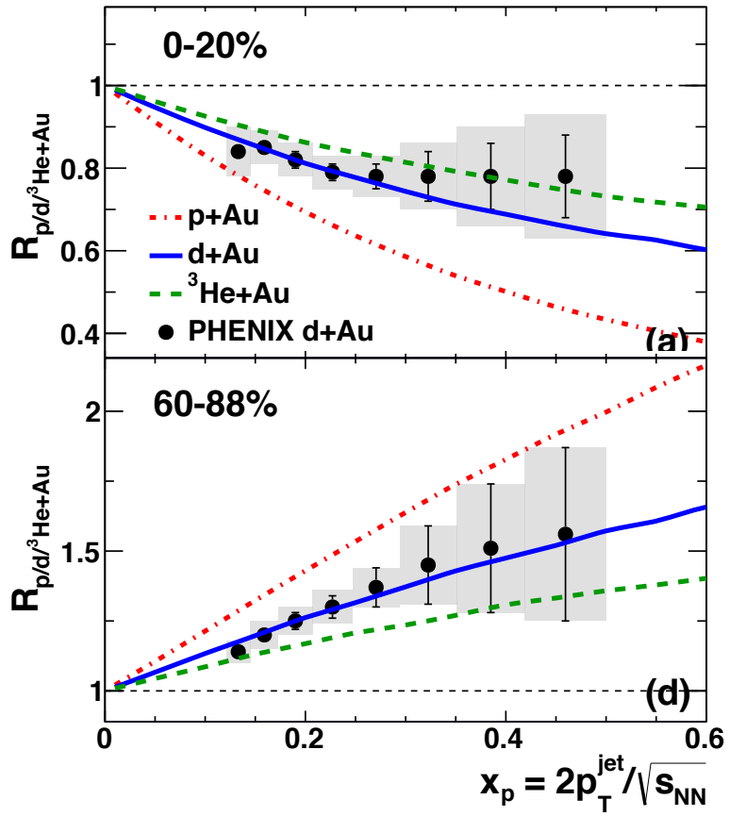




- PHENIX Collaboration, Centrality-dependent modification of jet-production rates in deuteron-gold collisions at $\sqrt{s_{NN}}$ = 200 GeV, Phys. Rev. Lett. 116 (2016)122301
- Measurement of nPDF / cold-nuclear matter effects over large kinematic range at RHIC
- First measured jet spectrum in non-p+p collision system at RHIC – finalizes QM'12 result; observation of qualitatively similar effects to p+Pb data at LHC

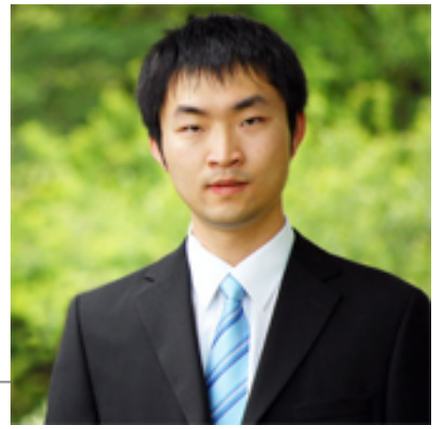
Possible *x*-dependent proton size fluctuations





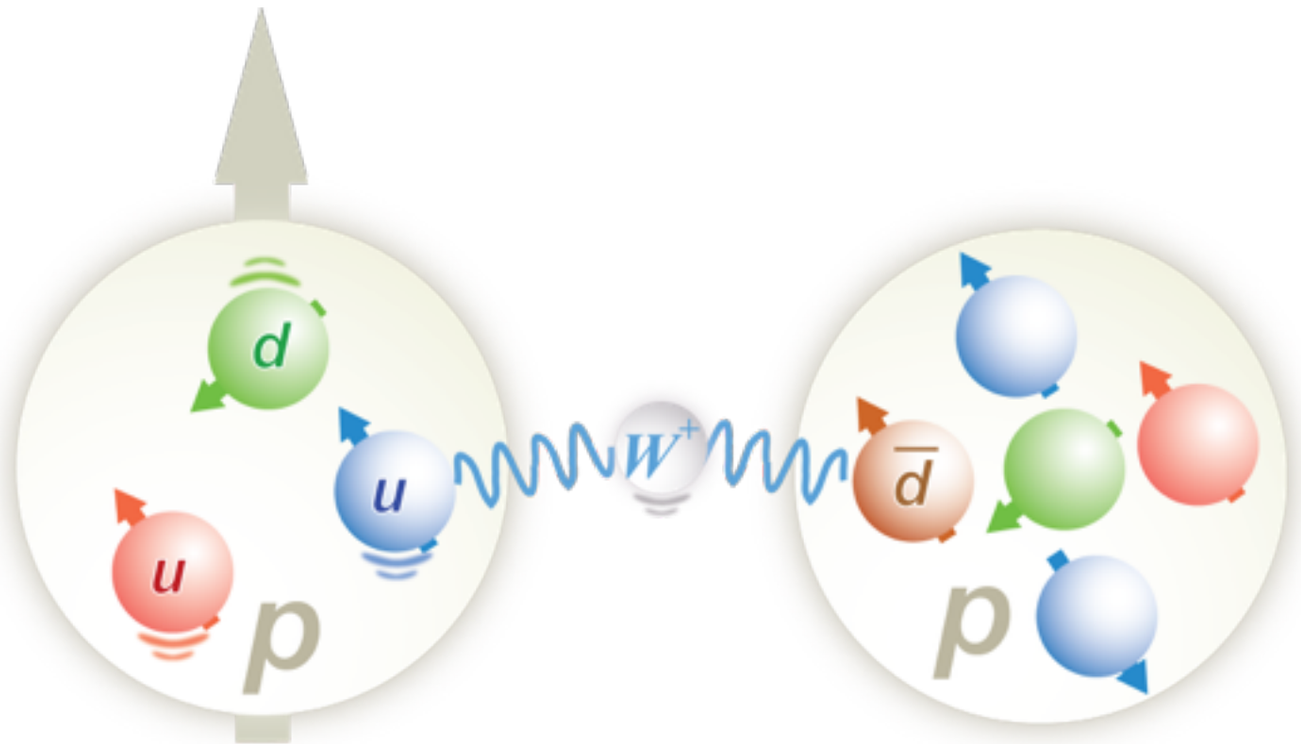
- Alvioli, Cole, Frankfurt, Perepelitsa, Strikman, Evidence for x-dependent proton color fluctuations in pA collisions at the CERN Large Hadron Collider, Phys. Rev. C93 (2016) 011902
  - ➡ explanation of p+Pb effects at the LHC as arising from “shrinking” or “weakly interacting” proton, with quantitative comparison of model to data
- McGlinchey, Nagle, Perepelitsa, Consequences of high-x proton size fluctuations in small collision systems at RHIC, nucl-th/1603.06607, Accepted by Phys. Rev. C
  - ➡ proposal to test shrinking proton picture with p/d/^{3}He+Au data at RHIC

Jin Huang

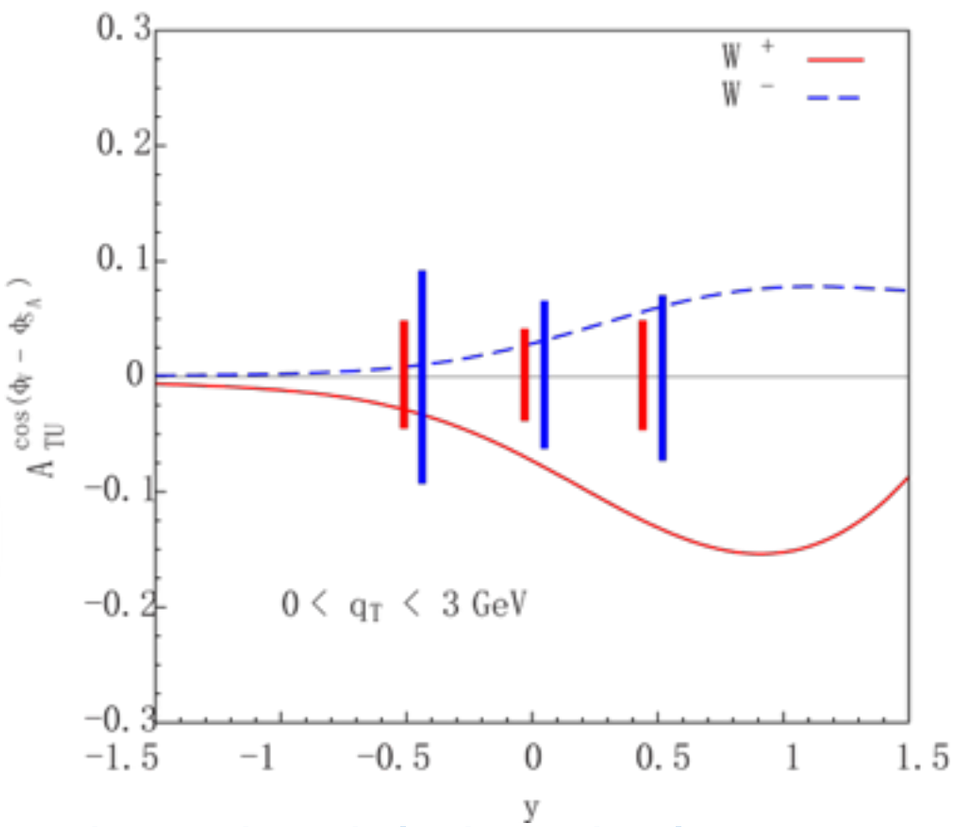


Huang, Kang, Vitev, Xing, PRD 93 (2016)

➢ Within TMD factorization formalism, we presented the cross sections for weak boson production in polarized pp collisions. And estimated the spin asymmetries at the top RHIC energy.



- **Curve:** Huang, Kang, Vitev, Xing, PRD 93 (2016)
- **Points:** Jin's naïve expectation of STAR Run17 projection based on Sivers A_N projection in RHIC Cold QCD plan



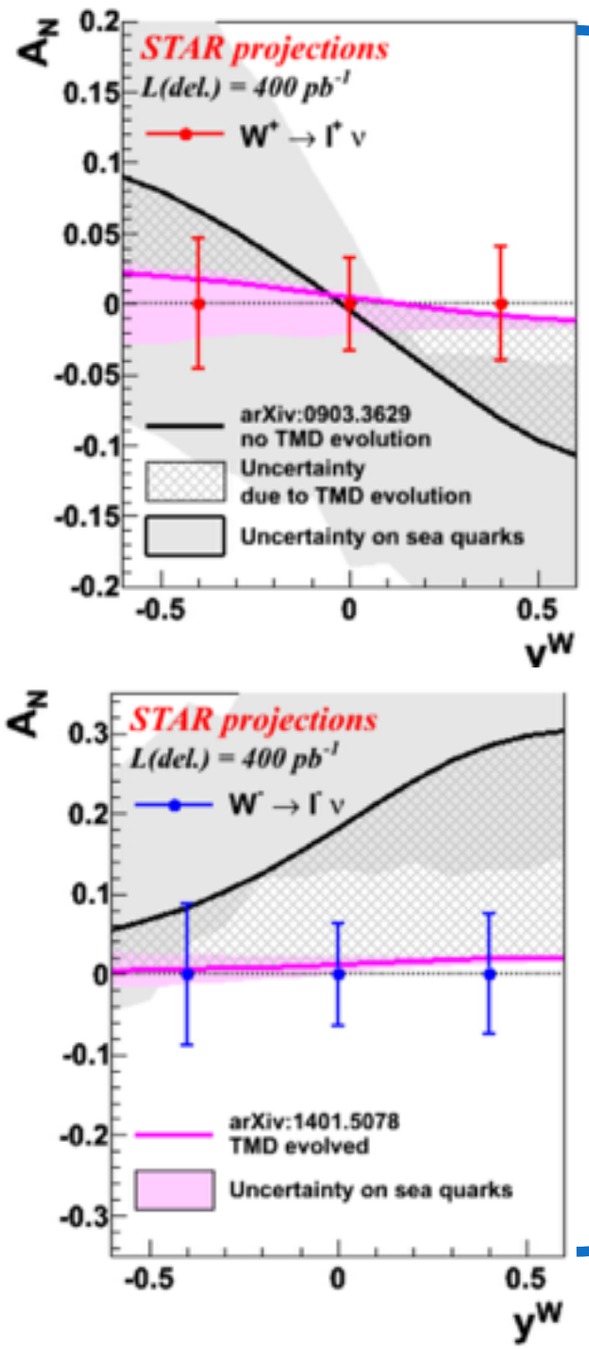
➢ Unique opportunity of probe transversal helicity g_{1T} via parity violating single transverse spin asymmetry. With Sivers measurements, comprehensive tests the universality properties of TMDs, constrains the TMD evolution effects

$$A_{TU}^{\cos(\phi_V-\phi_{S_A})}=\frac{F_{TU}^{\cos(\phi_V-\phi_{S_A})}}{F_{UU}},\quad F_{TU}^{\cos(\phi_V-\phi_{S_A})}=-\mathcal{C}^W\left[2v_q a_q\frac{\hat{q}_T\cdot\vec{k}_{aT}}{M_A}g_{1T}\bar{f}_1\right],\quad g_{1T}=$$

Experimental outlook: RHIC/STAR W in Run 2017

$p^{\uparrow}p \rightarrow W + X \rightarrow (e+\nu)+X$, transversely polarized p+p collision @ $\sqrt{s}$ = 510 GeV

STAR projection in RHIC cold-QCD WP



Measured at same time

P-conserving A_N | P-violating A_N

Probing TMD PDFs

$f_{1T}^{\perp}$ = – | g_{1T} = –

Modified universality for off-diagonal TMD

Sign change? | Universal?

Study evolution for TMD

Similar scale of evolution?

Model relation to OAM

Im(S * P) | Re(S * P)

- **Curve**: Huang, Kang, Vitev, Xing, PRD 93 (2016)
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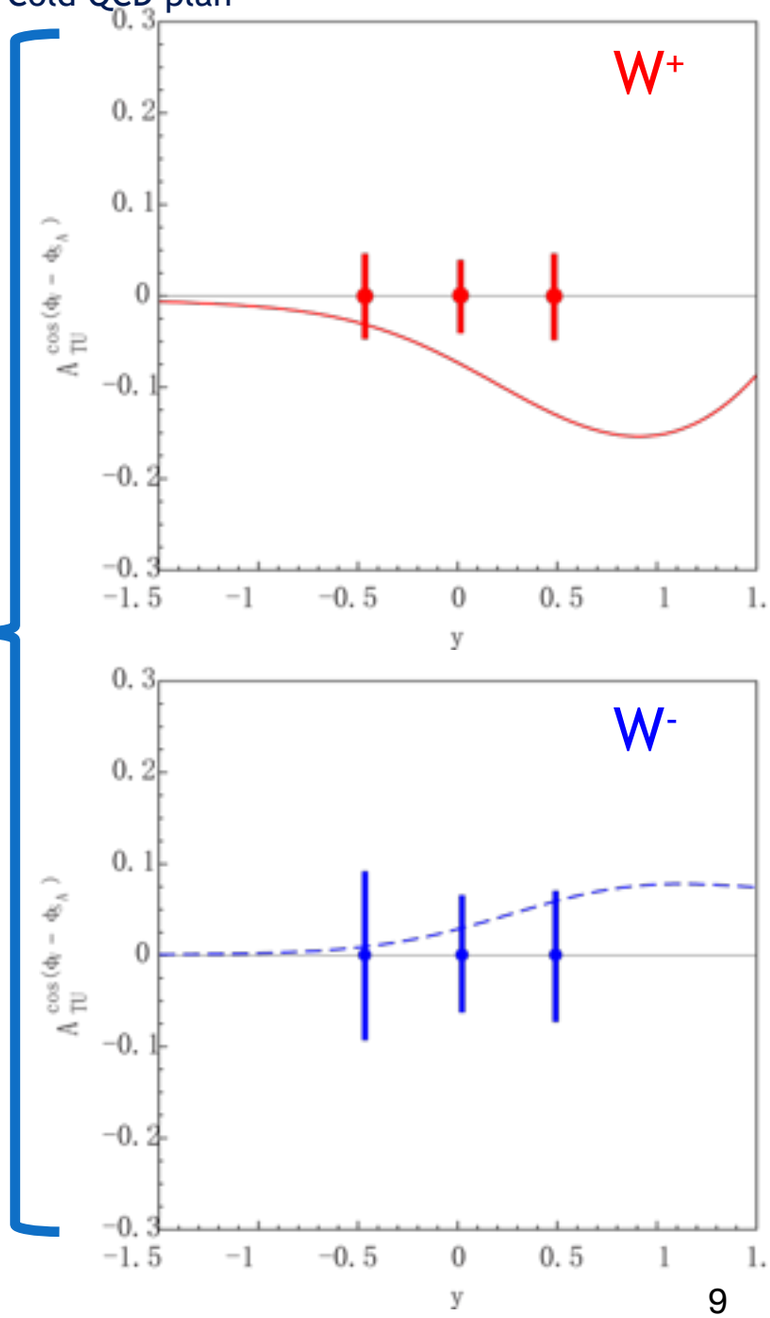
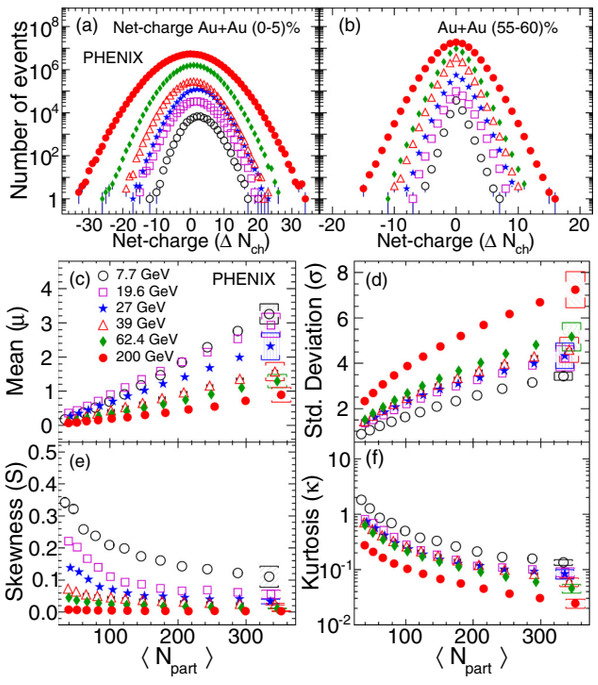
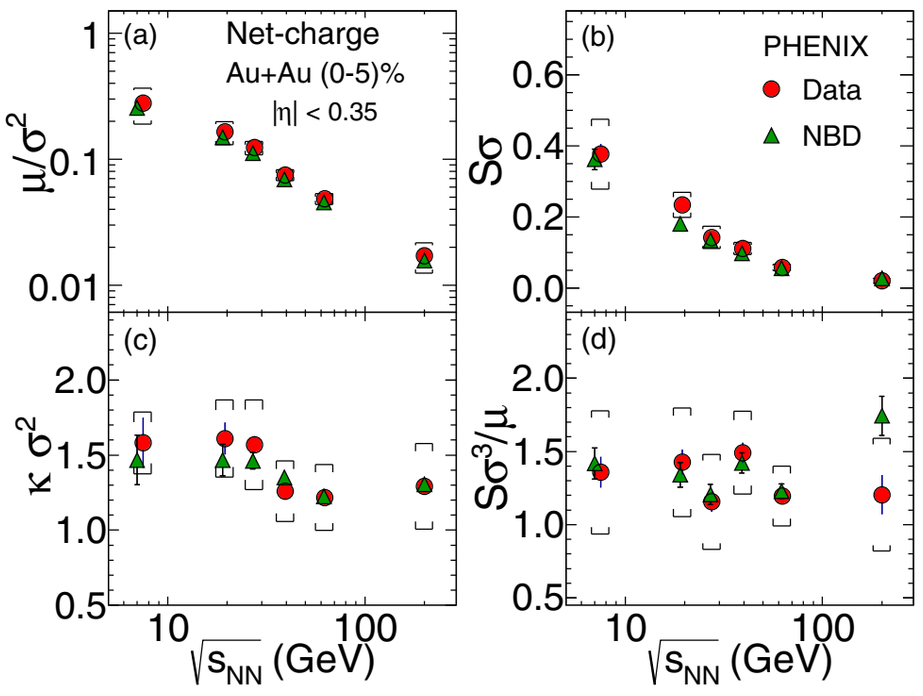


Net charge fluctuations

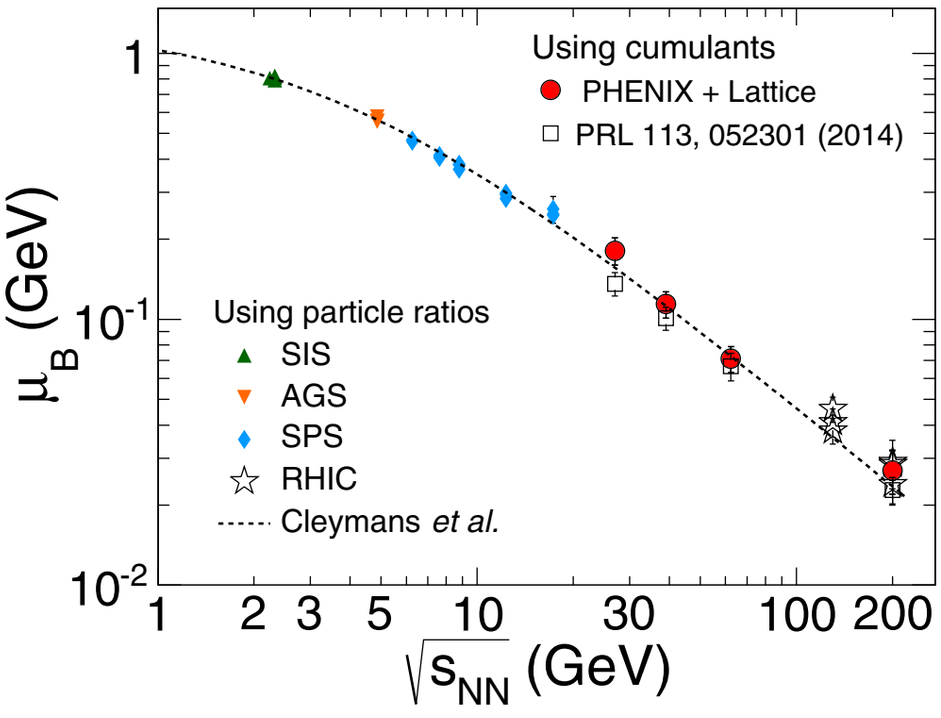
"Measurement of higher cumulants of net-charge multiplicity distributions in Au+Au collisions at $\sqrt{s_{NN}}$ = 7.7–200 GeV", Phys. Rev. C 93, 011901(R) 2016
(primary authors include Jeff Mitchell, Mike Tannenbaum)



uncorrected net charge distributions



products and ratios of cumulants of fully corrected distributions – dependence on volume drops out



with input from LQCD, determine μ_B and T_f vs $\sqrt{s_{NN}}$ with small uncertainties

sPHENIX physics

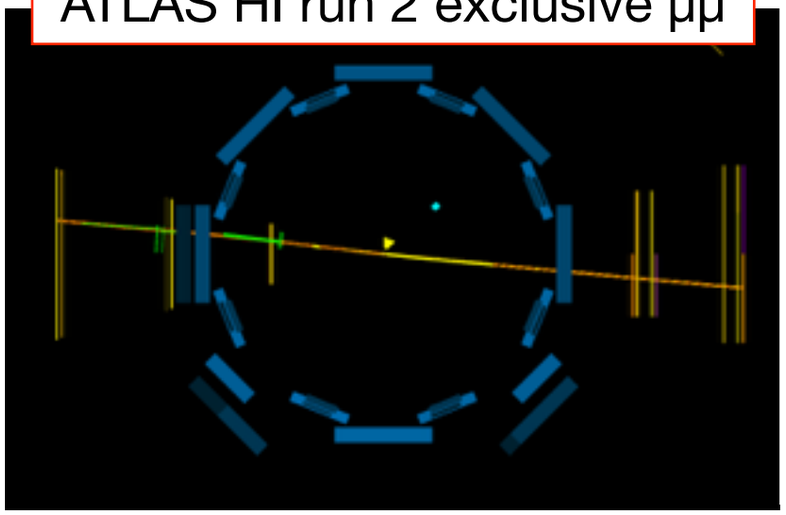
- b-tagging, now with full GEANT4 studies (Perepelitsa)
- EMCal simulations – relevance to Upsilons (Huang)
- Computational framework and code development (Pinkenburg, Purschke, Huang)
- Possible intermediate tracker (Nouicer)
- sPHENIX science case (Morrison, Huang, Perepelitsa)

Ultra-peripheral physics in Pb+Pb with ATLAS

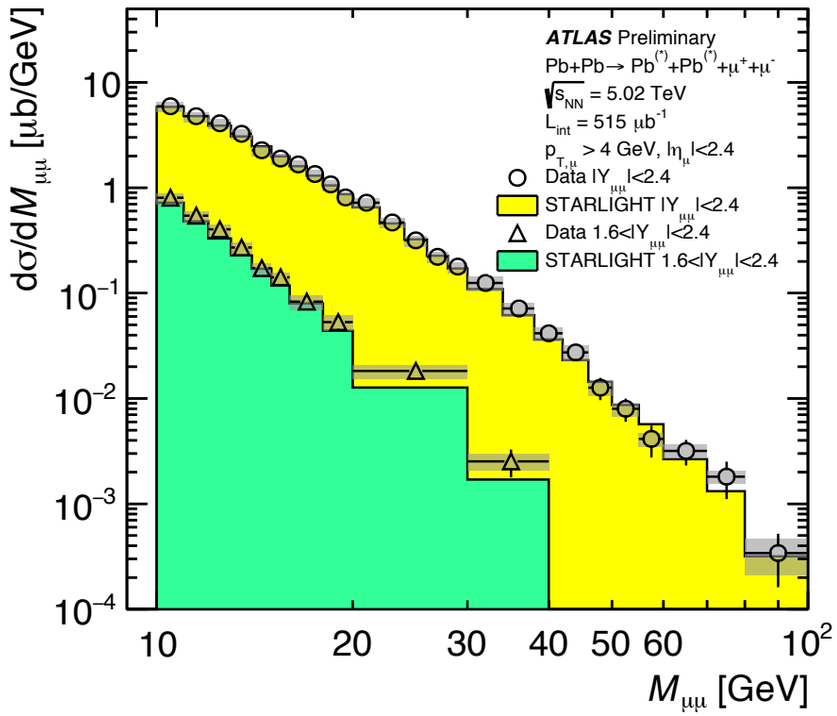
Strong EM fields, highly contracted:
source quasi-real photons to
probe nucleus (& nucleon in *p*+Pb).

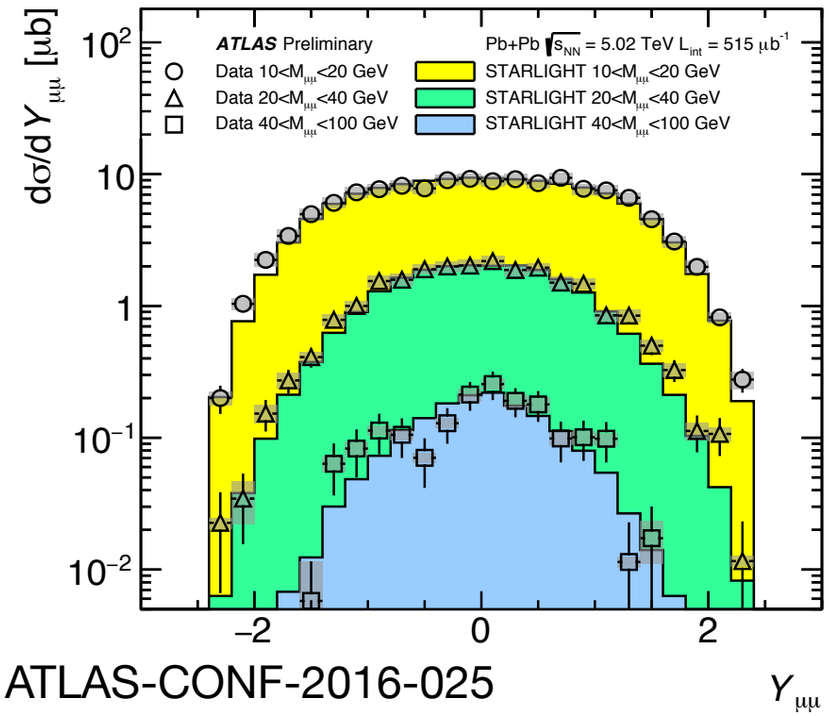
Possibility of “EIC physics” prior to EIC?

ATLAS HI run 2 exclusive μμ

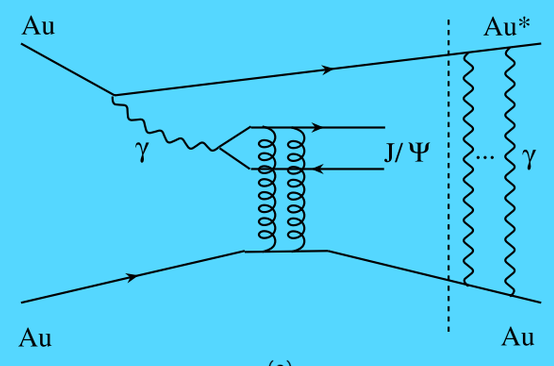


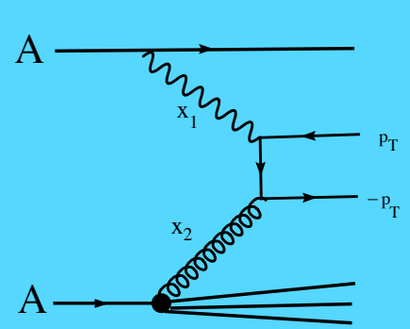
STARLIGHT MC implements collisions of
Weisacker-Williams quasi-real photons + QED μ± production

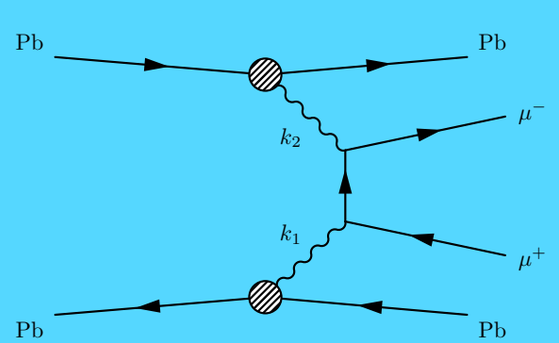




ATLAS-CONF-2016-025







Photon-pomeron:
production of vector mesons (sensitivity to nPDF)

Photo-nuclear:
jet photoproduction (probe nPDF directly)

Photon-photon:
dilepton production (& other exclusive states)

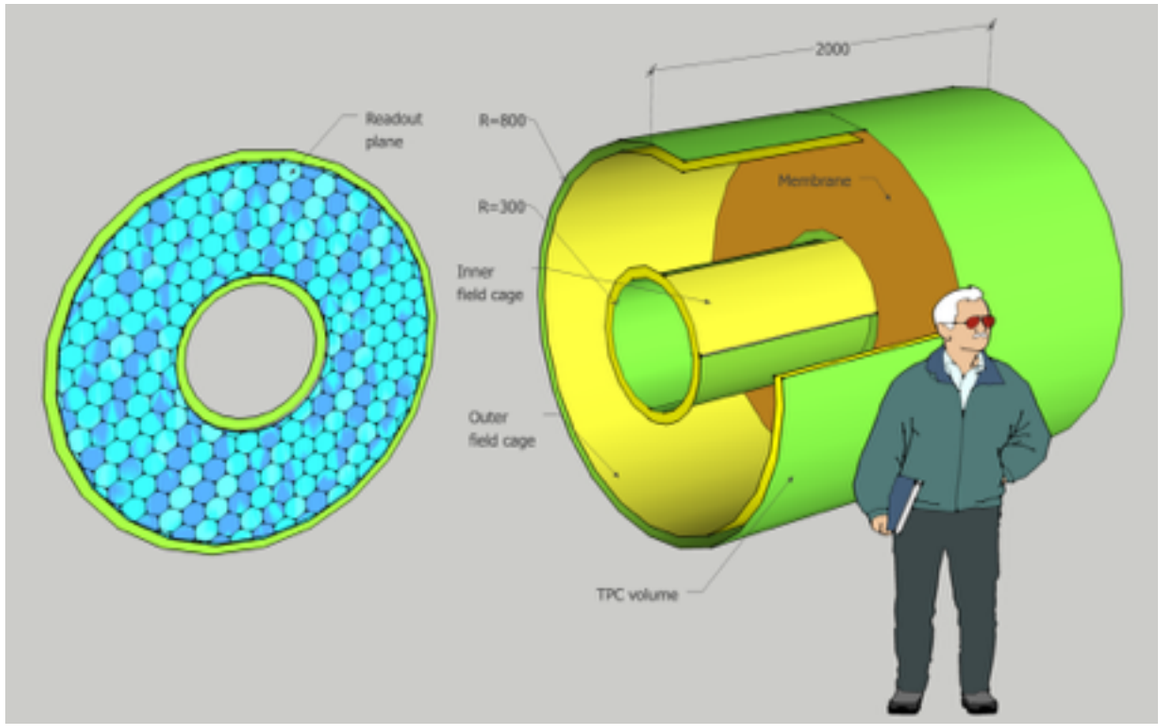
R&D activities

Tracking R&D

sPHENIX requirement driven by measuring Upsilons with $\Delta m/m \sim 100$ MeV/c

TPC + Si Vertex Detector

- Fast, compact TPC with GEM readout
- $\Delta R \sim 30$-80 cm, $L \sim \pm 1$ m
- $T_{drift} \sim 10$-20 μsec
- ~ 40 layers with $\sigma \sim 120$ μm per point
- Total thickness $\sim 3\%$ X_0
- Can be reused for eRHIC



SBU+Woody, Azmoun, Sakaguchi

Investigation of possible intermediate silicon strip tracker: Hamamatsu sensors being tested

RIKEN+Nouicer

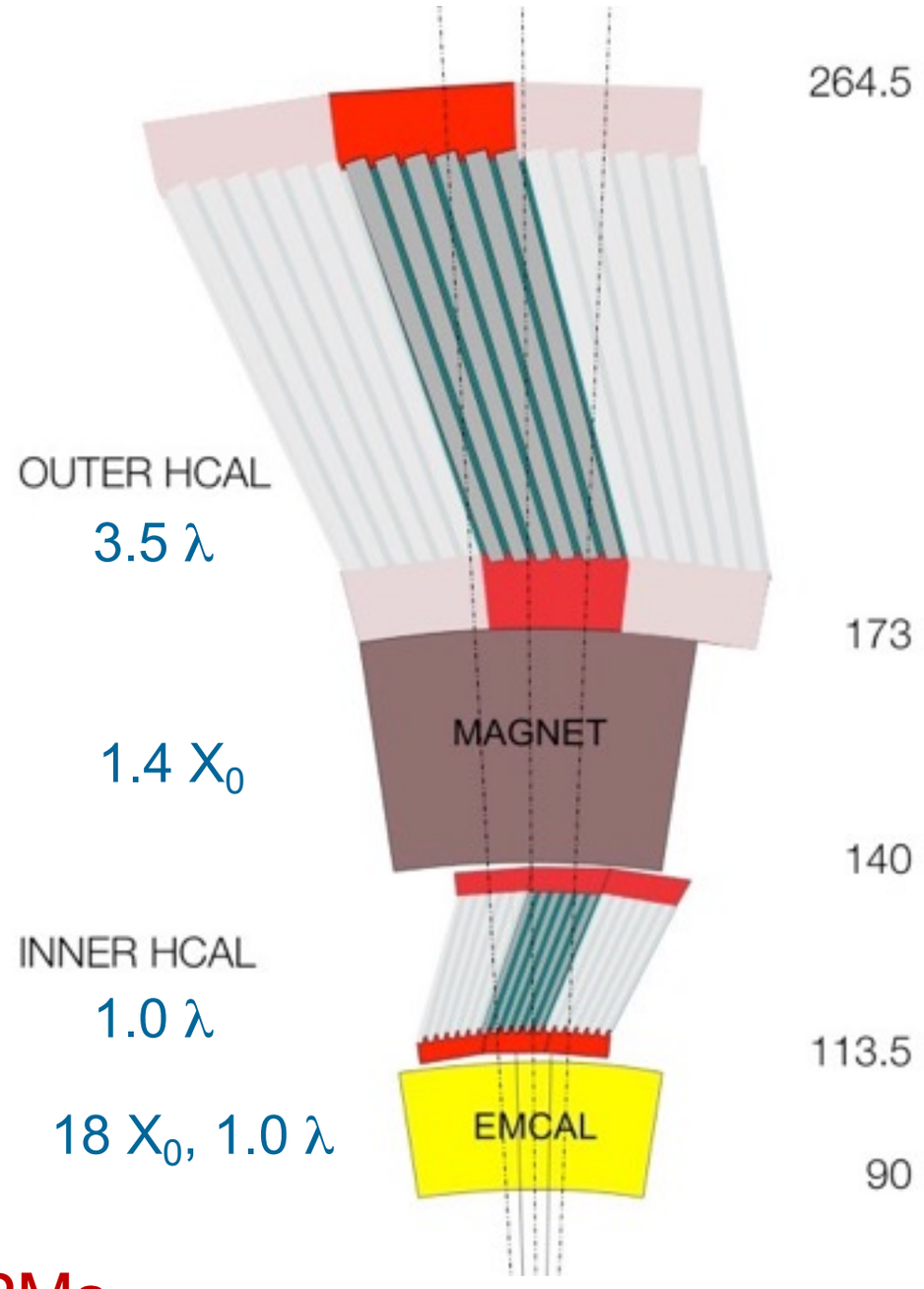
The sPHENIX Calorimeter Systems

EMCAL – Tungsten SciFi SPACAL

- ± 1.1 in η, 2π in ϕ
- $\Delta\eta \times \Delta\varphi \approx 0.025 \times 0.025$
- $\sigma_E/E < 15\%/\sqrt{E}$

HCAL – Steel plates + scintillating tiles with WLS fiber readout

- Plates are tilted to avoid channeling
- Two longitudinal sections (~ 4.5 λ)
  - Inner HCAL inside magnet
  - Outer HCAL outside magnet
- $\Delta\eta \times \Delta\varphi \approx 0.1 \times 0.1$
- $\sigma_E/E < 100\%/\sqrt{E}$ (single particle)



EMCAL + HCAL ~ 5.5 λ

Both EMCAL and HCAL read out with SiPMs

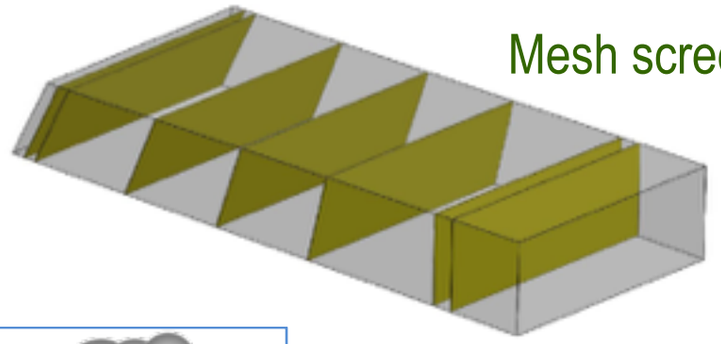
technicians, Kistenev, Haggerty

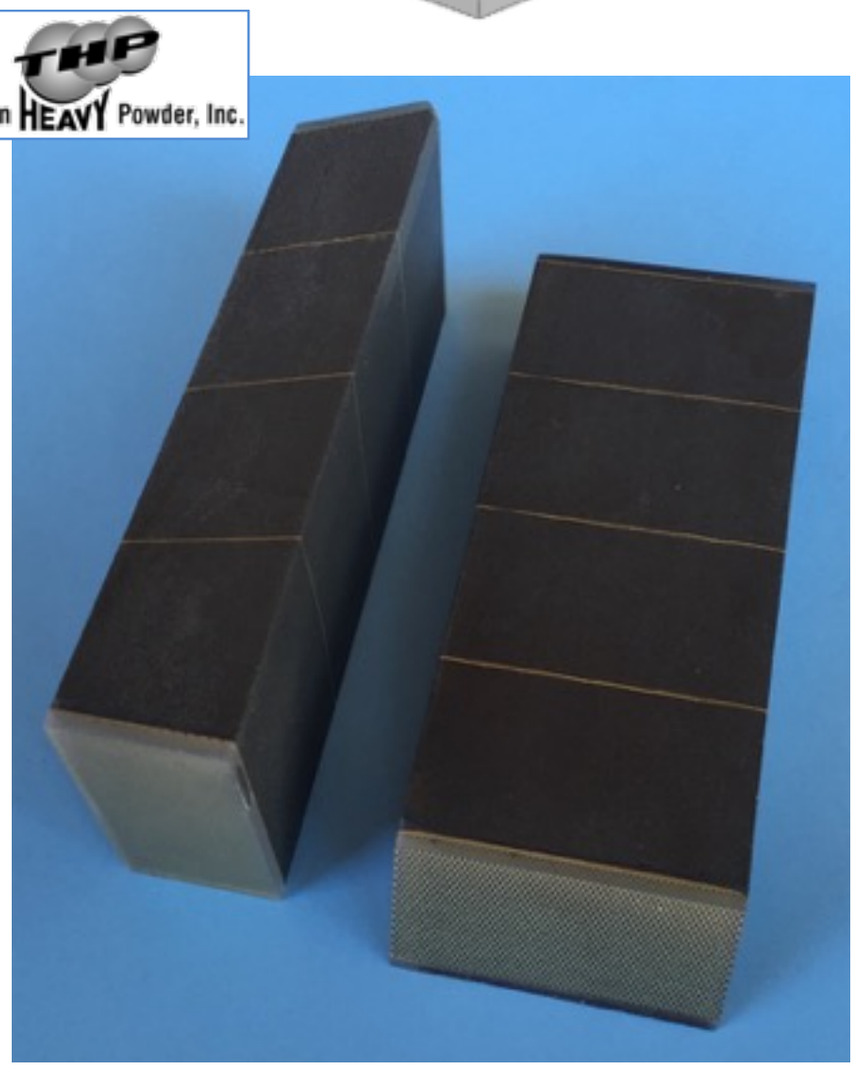
W/SciFi Modules

UIUC+Woody, Stoll

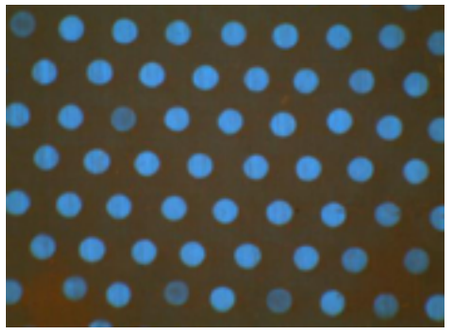
1D Projective

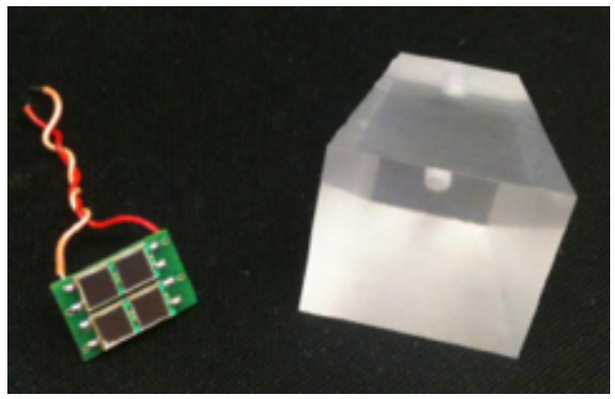
Mesh screens



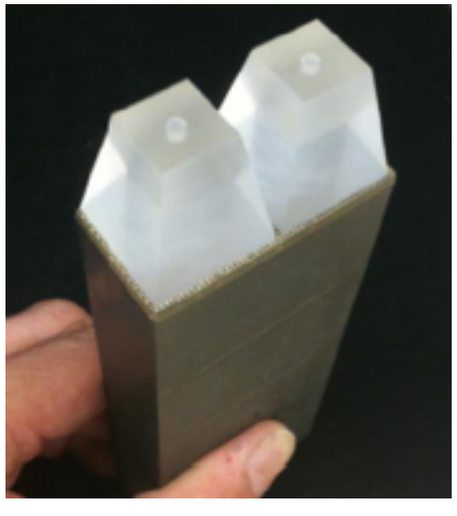


Fiber ends are finished by with fly cutting

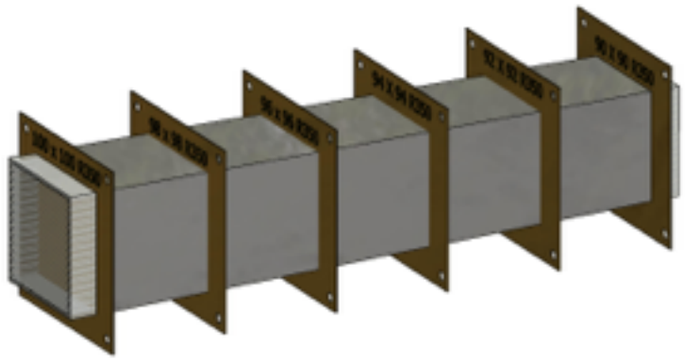


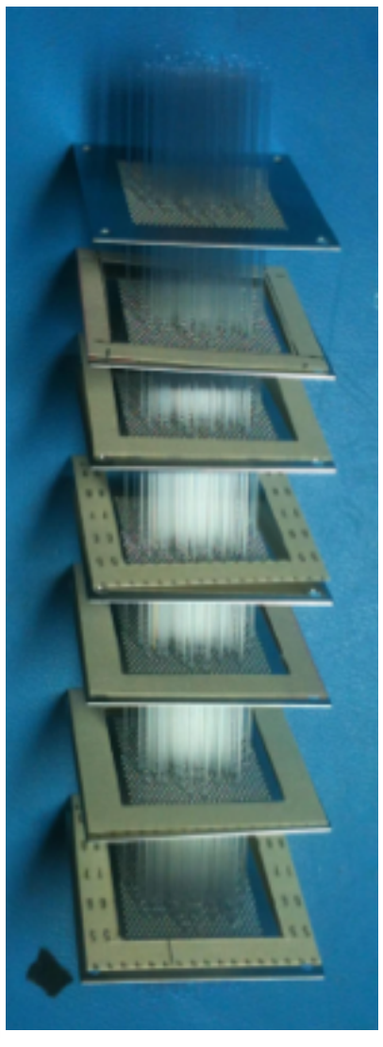


Light guides and SiPMs are attached to module ends to form towers



2D Projective

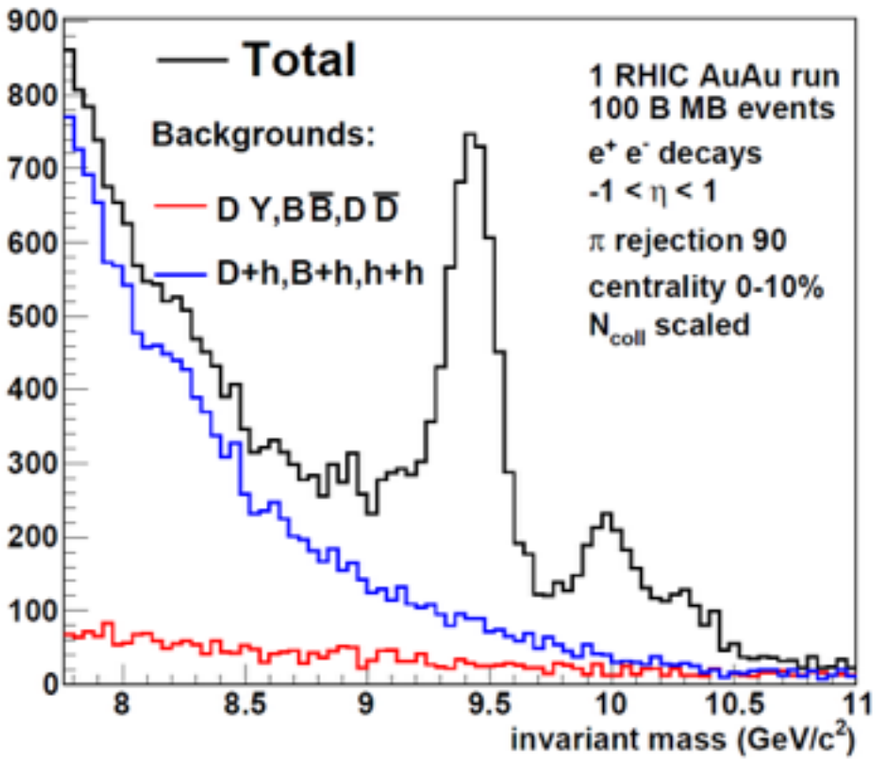




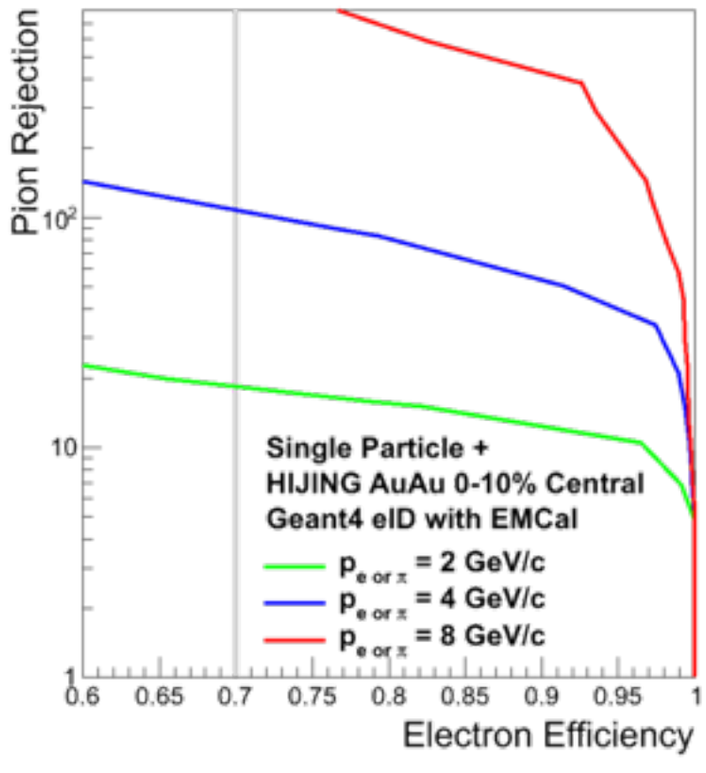
EMCal projectivity

Studying the degree to which a 2D projective calorimeter improves electron ID in HI

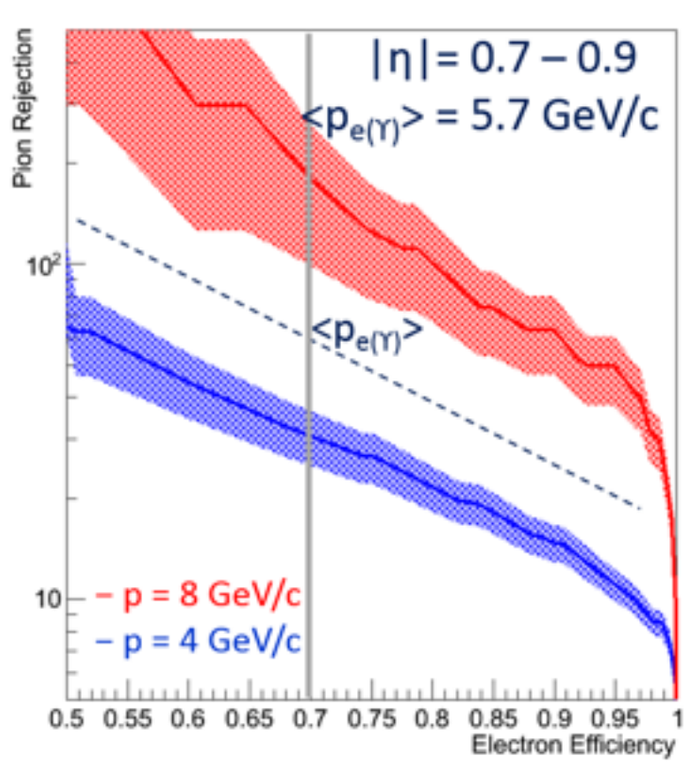
Require hadron rejection ~100:1 with electron efficiency ~ 0.7 to identify the Y with high efficiency



2D projective (equivalent)



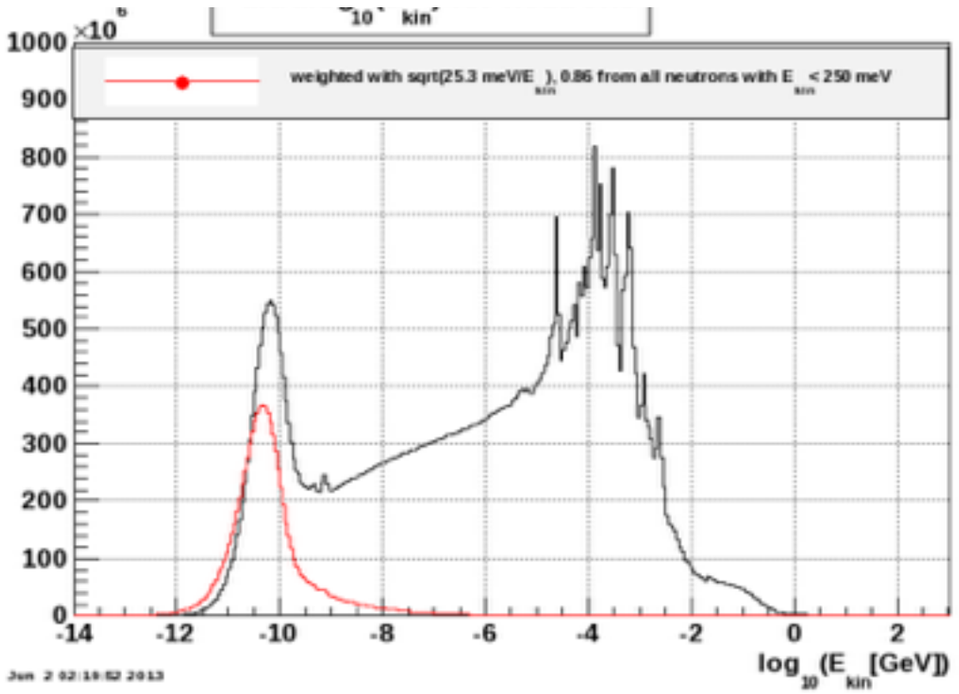
1D projective



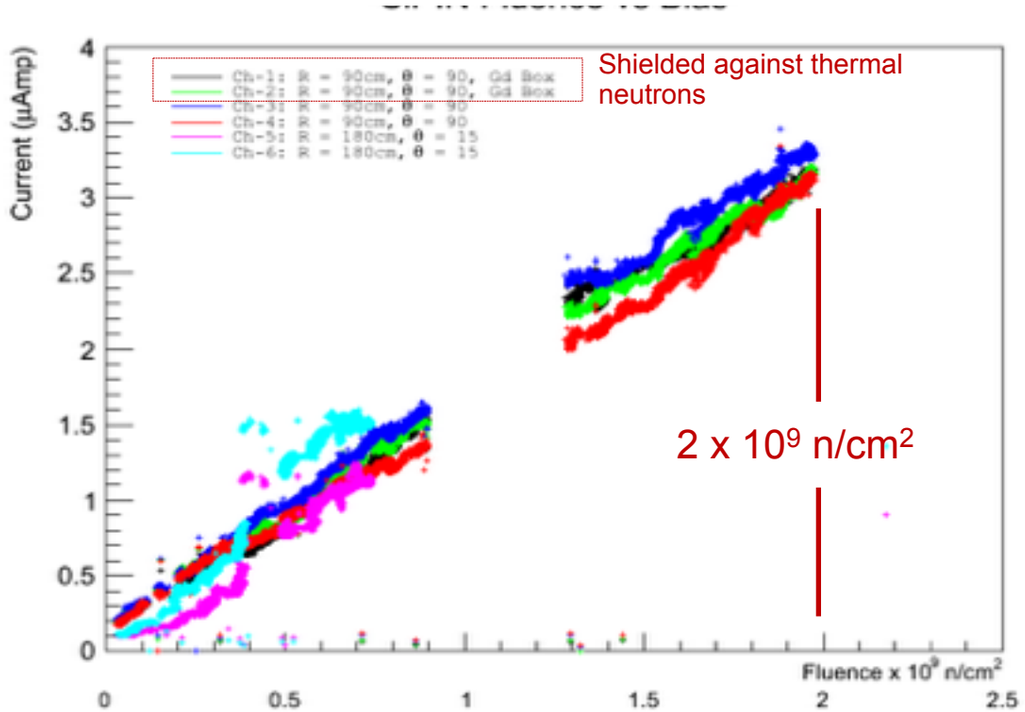
Huang

Radiation Damage in SiPMs

Estimated neutron flux in the STAR IR



Measured neutron flux in the PHENIX IR



Damage is caused mainly by neutrons (E ~ MeV)

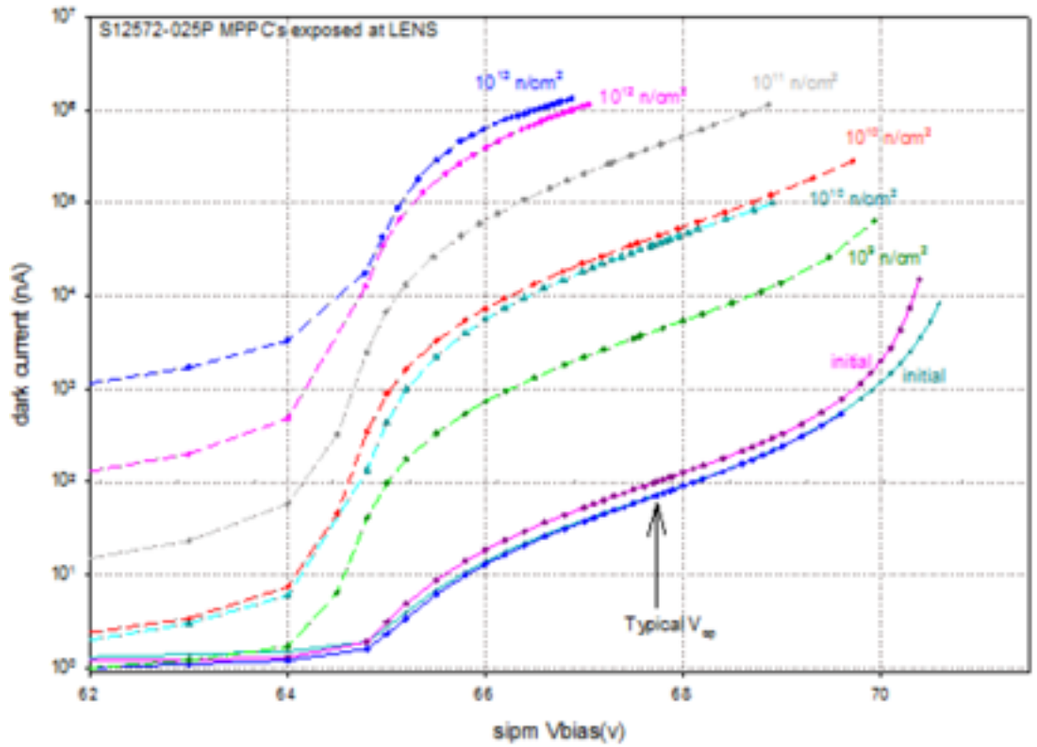
Measure thermal neutron flux in RHIC IR and estimate MeV equivalent neutrons using MC

Estimates in STAR for 2013 run (L=526 pb^{-1}):

R= 3-8 cm, |Z| < 10 cm : Φ_{eq} ~ 8×10^{10} n/cm^2

R= 100 cm, Z = 675 cm : Φ_{eq} ~ 2.2×10^{10} n/cm^2

Neutron measurements at the Indiana University LENS Facility



Haggerty

PHENIX open house

Achim Franz

Work by entire BNL/PHENIX technical crew to set up

Cloud chambers
Detector components
VR headsets

Summer Sunday 2016: 1400 visitors

Students very engaged in science activities

- PHENIX operations – shifts, data monitoring, analysis
- Wide array of summer R&D work
  - Abeliene Christian University (Rusty Towell and students)
  - Howard University (Marcus Alfred and students)
  - Stony Brook University (Spencer Locks (mech. engineering), others)

Summary

- Wide-ranging change underway
  - Scientific staff recently reduced by five FTEs; Goldhaber postdoc becoming Asst. Prof. at Colorado
  - Planning for rapid ramp-down in PHENIX operations manpower – towards 1.5 FTE
  - Anticipating sPHENIX needs, pivot in group's direction
- Significant challenge to maintain group's scientific prominence during this period – aim to hire key postdocs and staff